Casting simulation drives component development for High Pressure Die Casting

High Pressure Die Casting (HPDC) enables manufacturing of large thin-walled light-weight structural components.

To remain competitive in the new global marketplace, component manufacturers in the automotive and aeronautic industries are constantly being asked to increase efficiency while lowering production costs and shortening delivery times. This request from OEMs for product solutions with low energy consumption, in tandem with new requirements by the government for increased fuel efficiency, can be satisfied using light metals such as aluminium and magnesium.

High Pressure Die Casting (HPDC) enables manufacturing of large thin-walled light-weight structural components. In HPDC castings, a large number of different functions can be integrated in one highly complex component, thereby replacing a group of sub-components that need to be manufactured separately and assembled together.

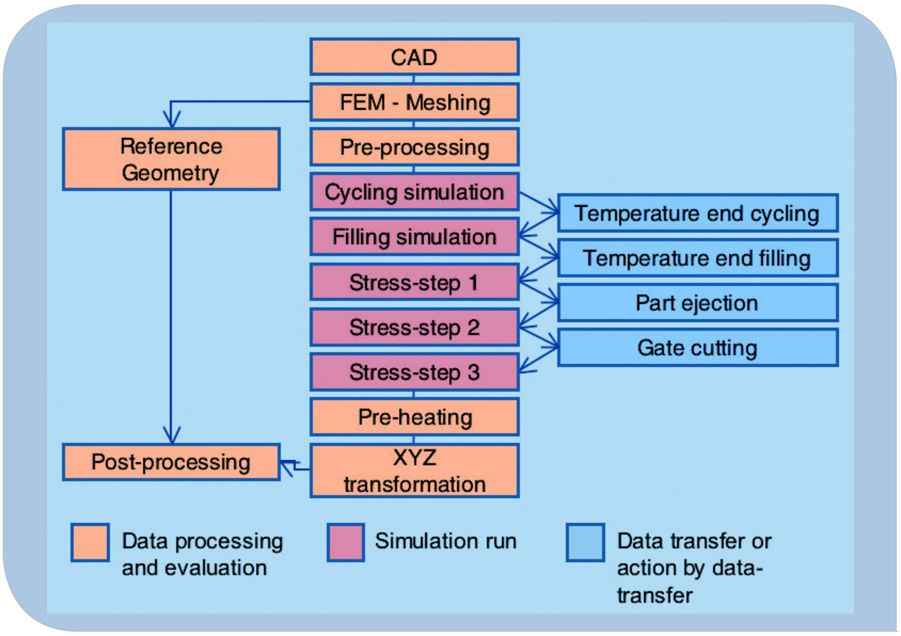

Fig. 2: Simulation procedure flow chart

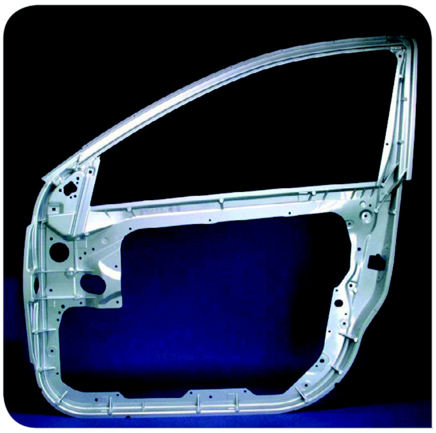

Fig. 1: Component Geometry

Georg Fischer Automotive AG has used HPDC on an interior door panel for example (Fig. 1).

In HPDC, the die being the heart of the process, the first step is to accurately model the thermal evolution of the die during the successive process phases: pre-heating, thermal ramp-up including metal injection, part cooling, part ejection, and die cooling, until "production state temperature" is reached.

The die shape is affected by the above thermal evolution, and in turn affects the way the injected metal flows and cools. Given the extreme sensitivity of thin-walled components, each part produced before the steady state temperature is attained differs from the previous in a non-negligible way.

Deformation Prediction by Using Casting Simulation

The most important aspects of the computer simulation are not only to capture all the physics of the process, but also to simplify the model in such a manner as to minimize the turnaround time without compromising on accuracy.

All steps of the simulation flowchart shown above (Fig. 2) were performed on the interior door panel model using ESI's ProCAST.

Die Cycling

A cyclic thermal simulation is performed to achieve the steady state temperature in the die. Process steps like die-opening, spraying and die-closing are described by time-dependent boundary conditions.

Die Filling

The filling of the cavity makes use of the steady-state temperatures attained from the thermal cycling simulation. The molten metal is injected into the die cavity based on the shot profile determined for this component. The result of this coupled fluid flow and heat transfer analysis is a filled cavity where the casting has a non-uniform temperature across the part.

Solidification and stress formation within the die

Small displacements in the casting appear in areas where the shrinkage is not prevented or constrained. In certain areas the casting part partially loses contact with the die cavity surface, which dramatically reduces the heat transfer between the casting and the die. ProCAST simulation tool automatically accounts for this by reducing the corresponding local heat transfer coefficient during solidification based on the thickness of the gap formed. In areas where shrinkage is prevented due to die constraints, stresses appear.

Solidification and stress formation after die opening

This part of the simulation focuses on the ejection of the casting and the subsequent cooling to room temperature. On ejection, the component tends towards a new equilibrium state when it is free from the constraints of the die. The stresses on the component are relaxed and transform to a corresponding amount of deformation (Fig. 3 and Fig. 4). The upper part of the door structure deforms inward and does not conform to the required tolerance.

Solidification and stress formation till room temperature after gate cutting

In this step the cutting of the gating system and the over flows are taken into account. Since the gating system is mostly hotter than the part, it

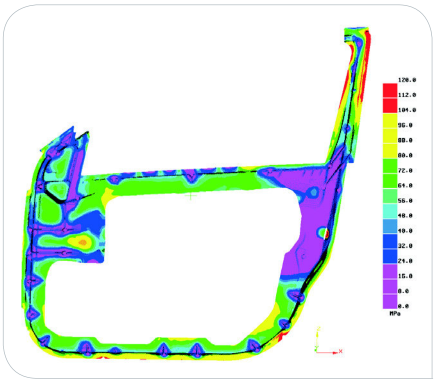

Fig. 3: Von Mises stresses before ejection

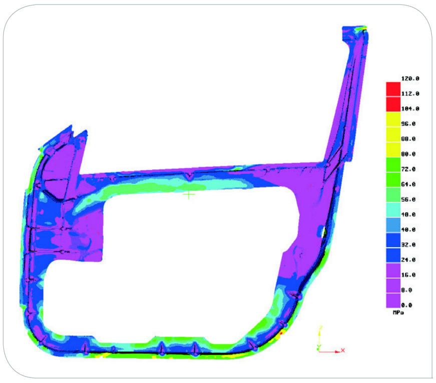

Fig. 4: Von Mises stresses after ejection

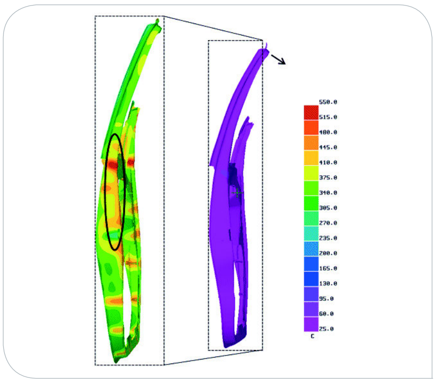

Fig. 5: Deformation and homogenization of the temperature after ejection and cooling down to room temperature

shrinks at a different rate than the component. As a result transverse stresses are initiated at the point of contact between the gating system and the part.

To conclude, the HPDC application enables large, thin-walled castings to be manufactured with a high degree of accuracy through the integration of multiple functionalities. An ambitious goal for the die design engineer during the process development stage is to maintain dimensional accuracy of the component while engineering the die and accommodating modifications during development and still be able to produce a quality part on the first run on the shop floor. Through casting simulation, one can estimate the effect of different relevant technical parameters, thereby avoiding potential problems in product ion.

On the door panel study presented, the achieved results (Fig. 5) corresponded quite accurately to the experimentally observed deformations. The component producer Georg Fischer Automotive was able to correctly identify the critical technical influences in the production process. By taking corresponding corrective measures, the demanded accuracy of the final geometric shape was achieved.

These results are only possible with a coupled heat transfer and stress analysis within an adequate and integrated automatic process simulation flowchart as developed and implemented by ESI in their casting simulation software.

Courtesy: Georg Fischer Automotive AG

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